Ultrasonic Brazing

Shankar P. Srinivasan, Ph.D and Dan Hauser, Ph.D
Edison Welding Institute

39th Annual UIA Symposium, Cambridge, MA, 2010
April 12, 2010

Work supported by the State of Ohio, Ohio Department of Development under an Edison Service Grant
Mechanics of Presentation

- Background on ultrasonic soldering
- Motivation
- Program Objectives
- Experimental
- Results
- Summary
Background on Ultrasonic Soldering

- Decades old technology
- Ultrasonic soldering is the process of pretinning or metallizing the surface of any material without flux
- Cavitation mechanism
- Benefits of flux elimination
  - Cost of flux and post-solder cleaning operations
  - Elimination of potentially hazardous exposure
  - Elimination of corrosion due to flux residue
- This process also obviates the use of platings on difficult-to-wet materials
Ultrasonic Soldering at EWI

- Dissimilar materials
- EWI SonicSolder™
- Various frequencies
- Customized tool design

- Glass-to-Ceramic Seal

- Nitinol Ribbon (0.0014- × 0.006-in.) to Nitinol Tube (0.008-in. OD)

- Glass-to-Metal Joint

- 25-mm SiC to Ti-6-4

- Commercial Unit (left) vs. EWI Design (right)
Motivation

- Ultrasonic Soldering is currently limited by the relatively low melting point of solders, and associated lower strengths (for e.g., 231°C for EWI’s Sn-Al SonicSolder™, and its strength 4-5 ksi in shear).

- Benefits of ultrasonic brazing
  - Allow brazing in air without flux.
  - Permit brazing of non-metals without metallizing/plating
  - Enable reflow brazing of components and applying metallizations that have melting temperatures greater than those of solders (>450°C).
  - Attain shear strengths greater than those obtained with solders (2-5 ksi).
Program Objectives

- Develop and demonstrate ultrasonic brazing process
  - Higher temperatures
  - Different part geometries
  - Dissimilar materials
- Define best practices and process envelope for high-temperature ultrasonic brazing
Experimental

- **Joint Geometry:** Single lap (flat geometry)
- **Substrates**
  - Similar Metals: 304 SS, Ti-6Al-4V
  - Dissimilar Materials: Boron Carbide to Steel
- **Filler Metals**
  - Al-12Si (Brazing temperature ~600°C)
  - Al (Brazing Temperature ~700°C)
- **Single lap dimensions:** 2” x 1” x ¼” with 1” overlap
- **Tubular:** Dissimilar Metal Brazing of 321SS -17-4PH steel
- **Brazing atmosphere:** Air
**Ultrasonic Brazing**

- **Sonotrodes:** Stainless steel horn tuned to operate at brazing temperatures
- **Ultrasonic Brazing:** 30 KHz, 350 W power, 70% amplitude
  - Ultrasonically pretin/metallize both surfaces with the molten filler metal
  - Reflow on stainless steel jig on hot plate
  - Transfer to RT to form the joint
- **Joint strength evaluation:** Compressive shear
Heated Ultrasonic Sonotrode
Process Basics

- Preheat the sonotrode
- Preheat the work piece
- Wet the iron with brazing filler metal
- Ultrasonically activate the sonotrode while in contact with the work piece

Ultrasonic pretinning oxidized Ti-6Al-4V

Heated sonotrode
Hot plate
Ultrasonically Brazed Specimens

Al-12Si/304 Stainless Steel

Al-12Si/Ti-6Al-4V

1100 Al/Ti-6Al-4V
Compressive Shear-Test Specimen
Compressive Shear Strength Data

<table>
<thead>
<tr>
<th>Filler Metal and Base Metal</th>
<th>Ultrasonically Soldered</th>
<th>Ultrasonically Brazed</th>
</tr>
</thead>
<tbody>
<tr>
<td>SonicSolder™ Ti-6Al-4V</td>
<td>5.2</td>
<td>10.1</td>
</tr>
<tr>
<td>SonicSolder™ Ti-6Al-4V + 10% WC</td>
<td>6.4</td>
<td>8.0</td>
</tr>
<tr>
<td>SonicSolder™ Ti-6Al-4V + 3003/4004</td>
<td>7.7</td>
<td>14.6</td>
</tr>
<tr>
<td>Al-12Si Type 304</td>
<td>10.1</td>
<td>8.0</td>
</tr>
<tr>
<td>Ti-6Al-4V Type 304</td>
<td>8.0</td>
<td>12.0</td>
</tr>
<tr>
<td>B4C-Steel</td>
<td>4.4</td>
<td></td>
</tr>
</tbody>
</table>
B₄C-Al Filler metal interface
Ultrasonic Brazing of Dissimilar 321 to 17-4PH Stainless Steel Tubing
Type 321 to 17-4PH Stainless Steel
Summary

- Ultrasonic Brazing in air without flux has been demonstrated on similar metals as well as on dissimilar metals and materials including ceramics.
- Ultrasonic brazing in air at ~600°C using Al-12Si filler metal has been demonstrated on flat stainless steels and titanium alloys.
- Ultrasonic brazing at ~600°C using Al-12Si has also been demonstrated on tubular geometries of dissimilar stainless steels.
- Ultrasonic brazing at temperatures at or greater than 700°C is feasible but oxidation of filler metal appears to result in lower than expected strengths. Brazing at these temperatures may require controlled atmospheres to prevent filler metal oxidation.
Questions

Shankar P. Srinivasan, Ph.D
EWI

614-688-5059
ssrinivasan@ewi.org